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(54) **SINGLE LAYER SENSOR PATTERN**

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(57) **ABSTRACT**

(65) **Prior Publication Data**

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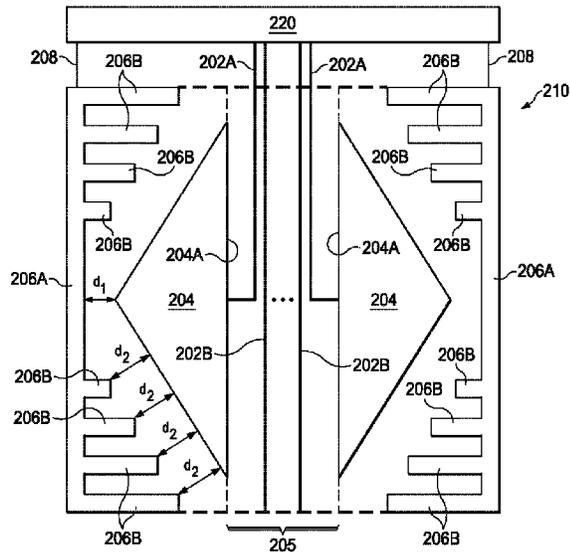
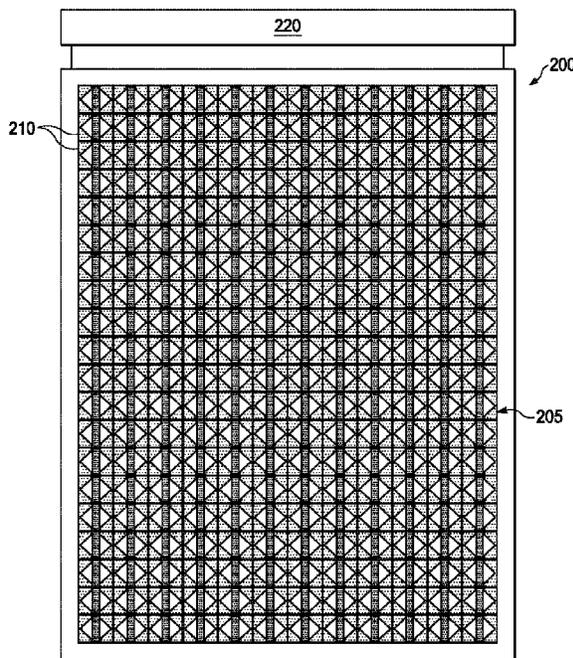
A single ITO layer design for a touchscreen panel incorporates a matrix of sensor cells formed from a single ITO layer of capacitive sensor pads, sensor bars, force lines and sense lines. Columns of multiplexed force lines are connected to rows of sensor pads to form force trees such that the force line of the end pair of sensor pads has a wide track, with the force lines of each subsequent pair of sensor pads having a reduced track width. Disposed between the columns of force trees, the matrix of sensor cells also includes columns of sensor bars connected to control circuitry via sense lines. The control circuitry applies a signal to the force trees to generate capacitance between rows of sensor pads and adjacent sensor bars. The control circuitry senses changes in the capacitance and resolves the location of a user touch in the matrix of sensor cells.

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(52) **U.S. Cl.**
CPC **H03K 17/9622** (2013.01); **G06F 3/044** (2013.01); **H03K 2017/9602** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.



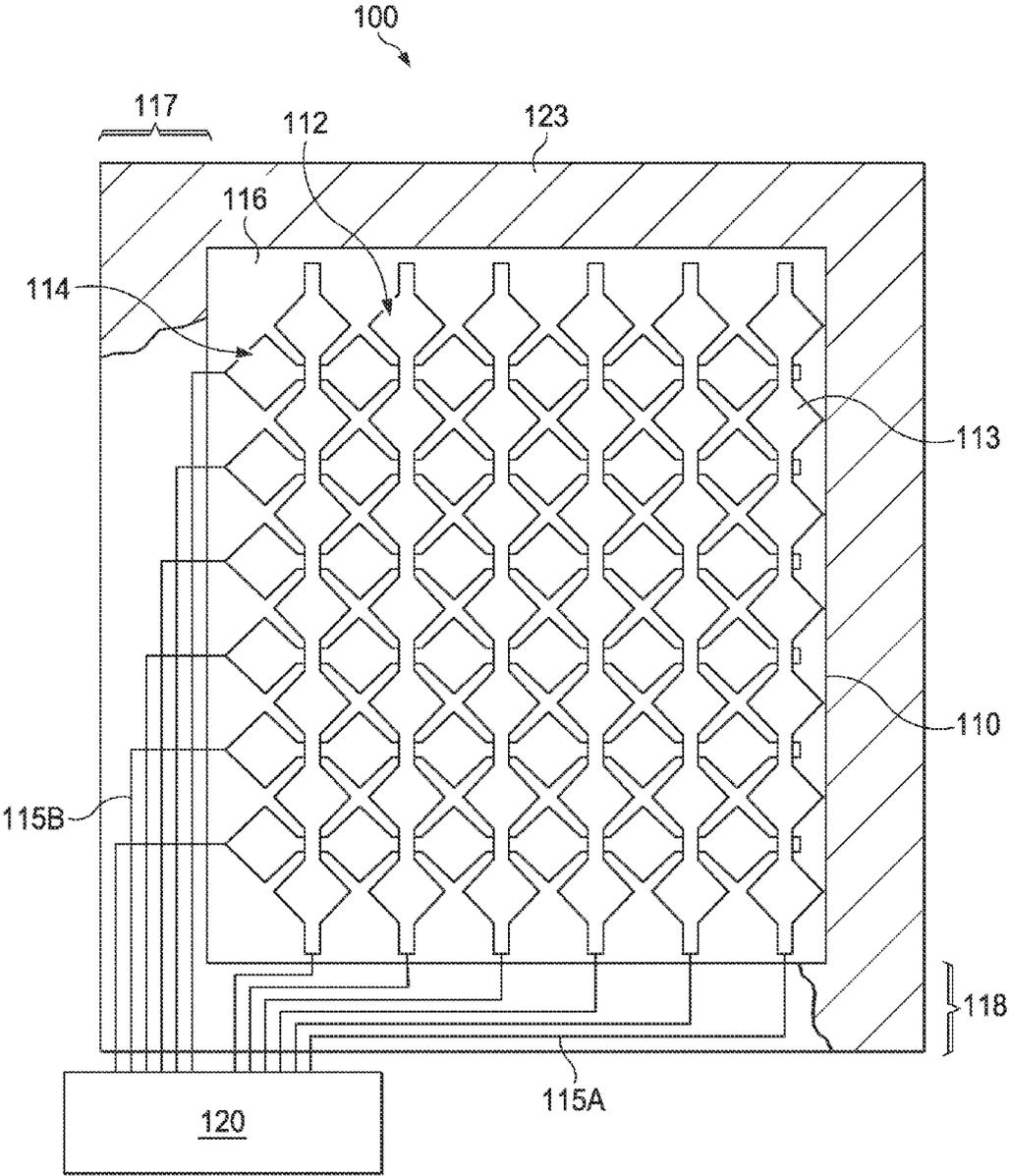


FIG. 1
(PRIOR ART)

FIG. 2A

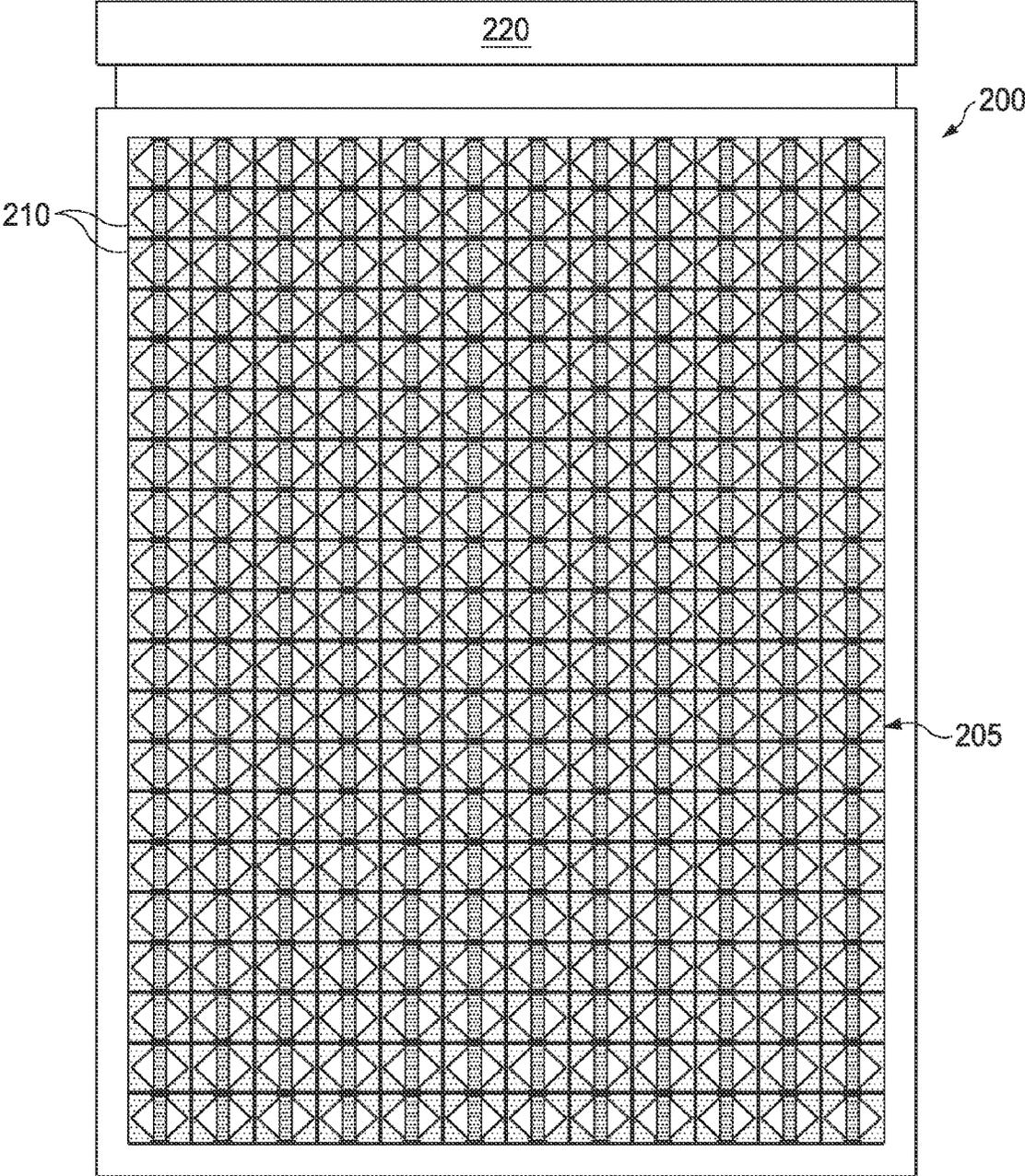


FIG. 2B

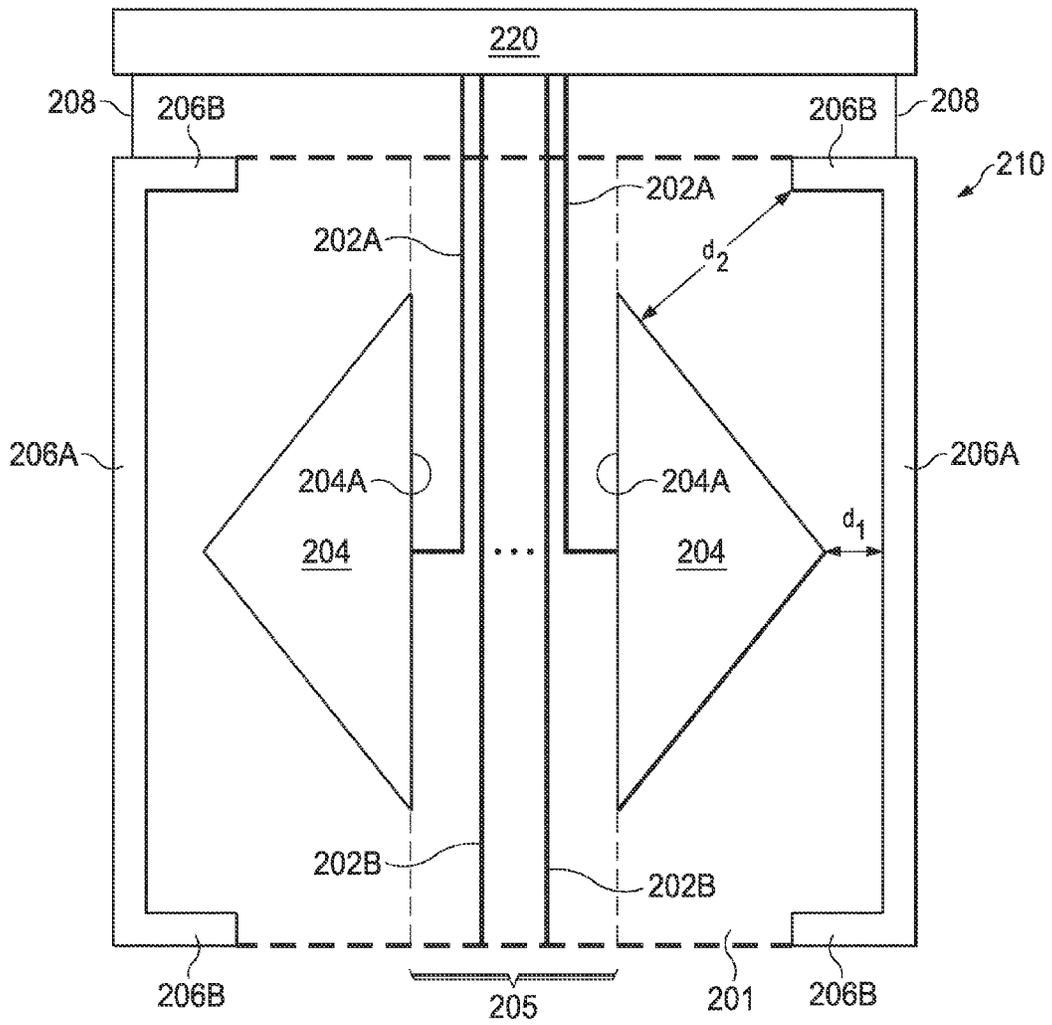
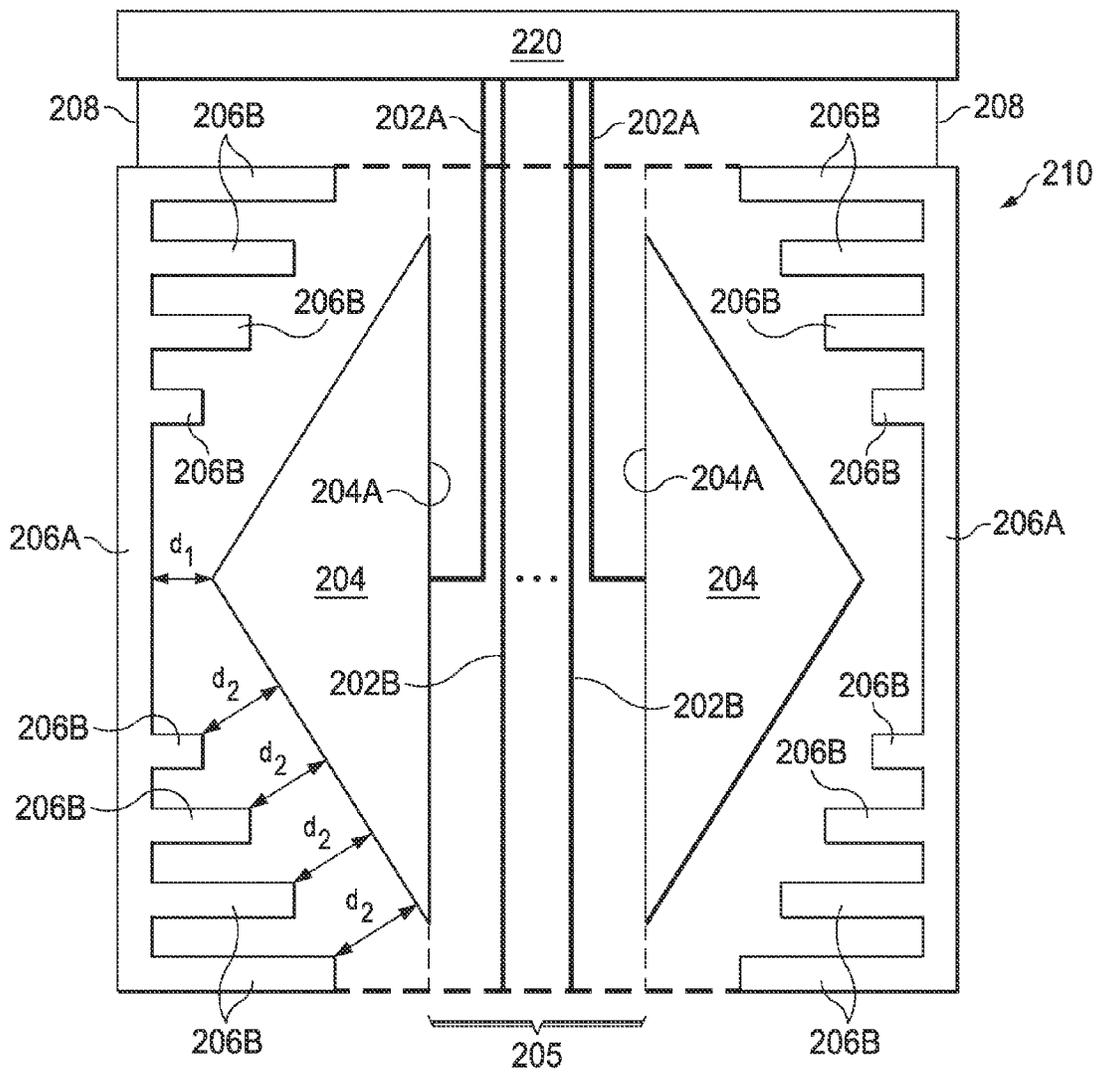


FIG. 2C



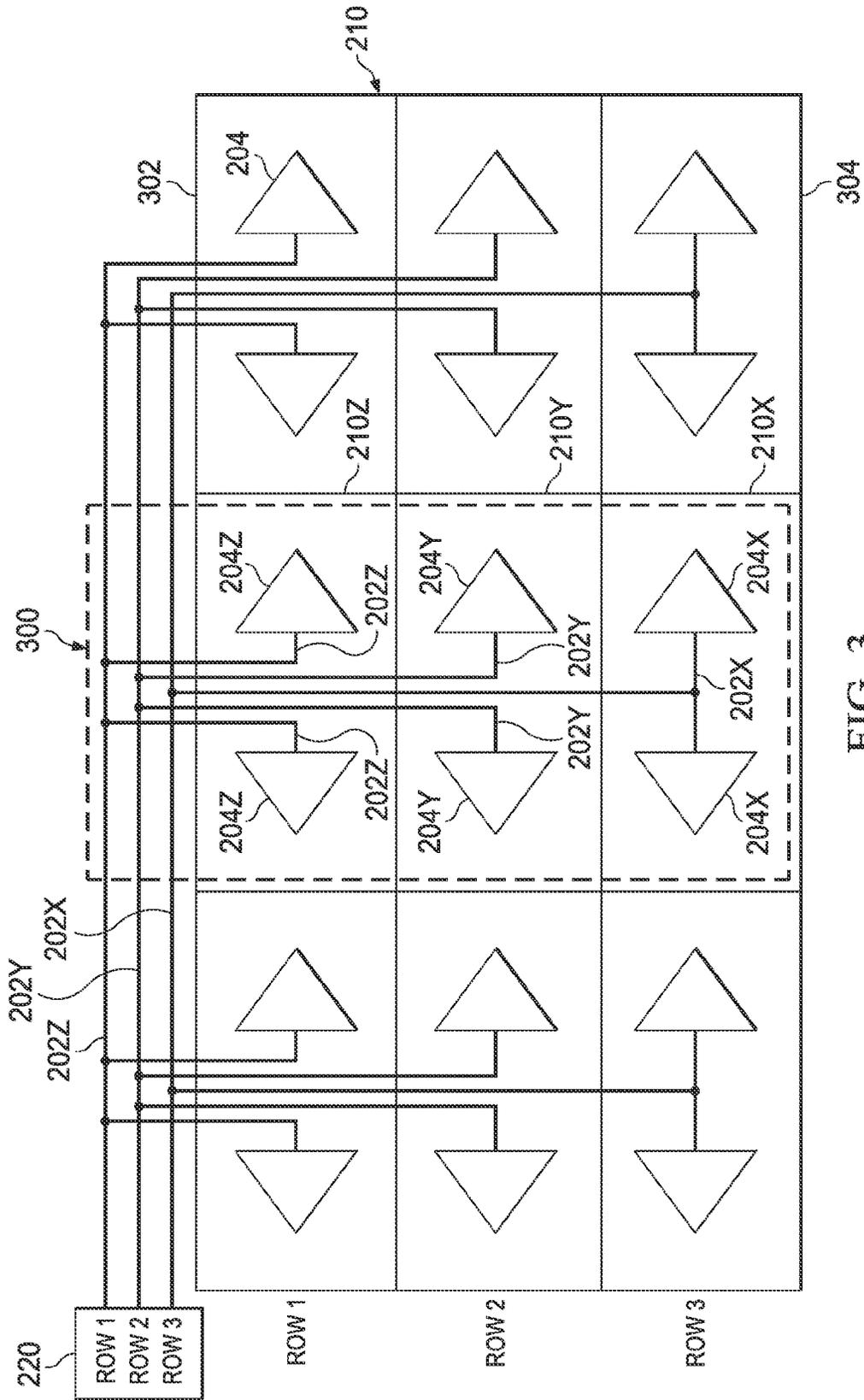


FIG. 3

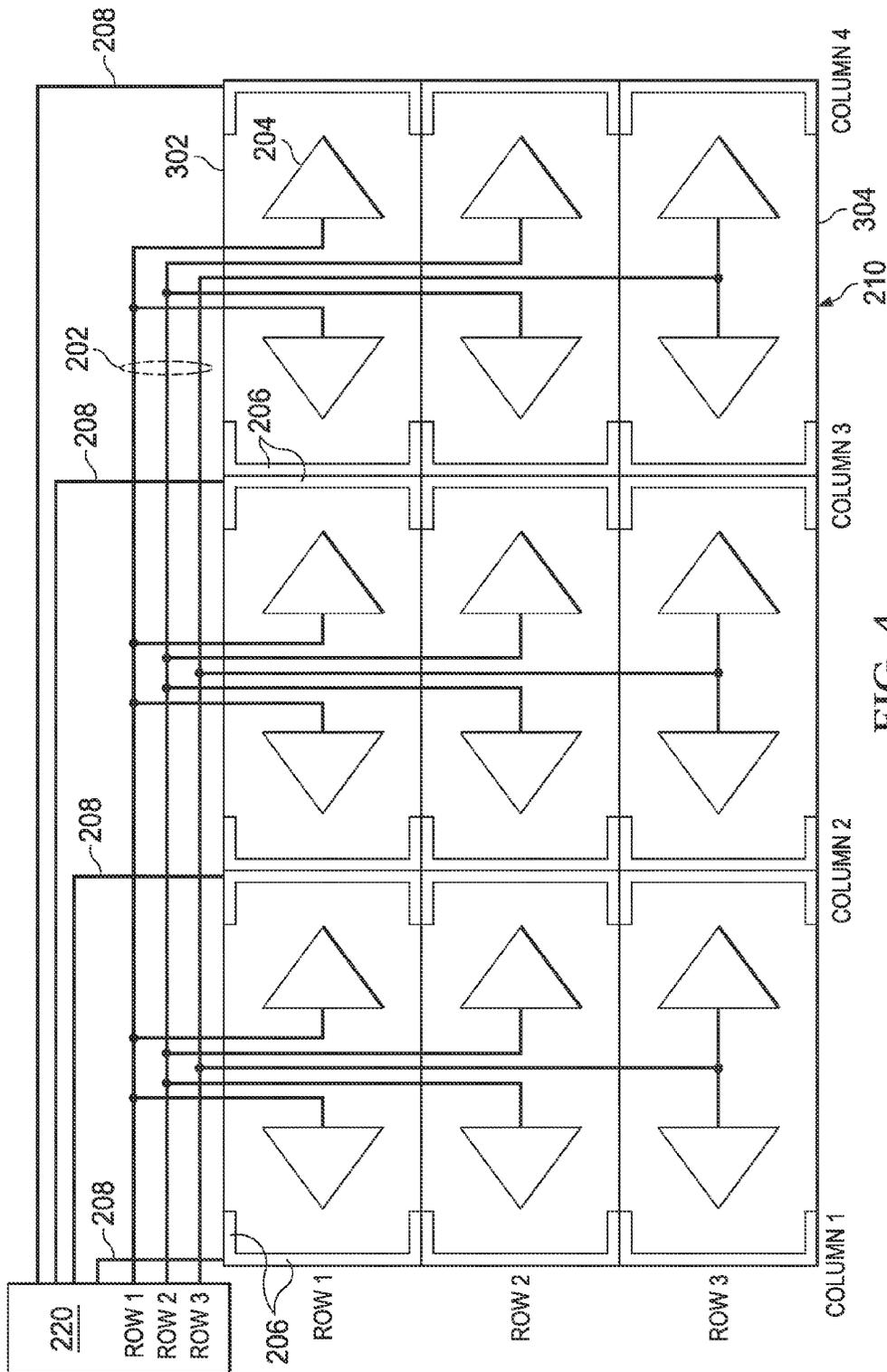


FIG. 4

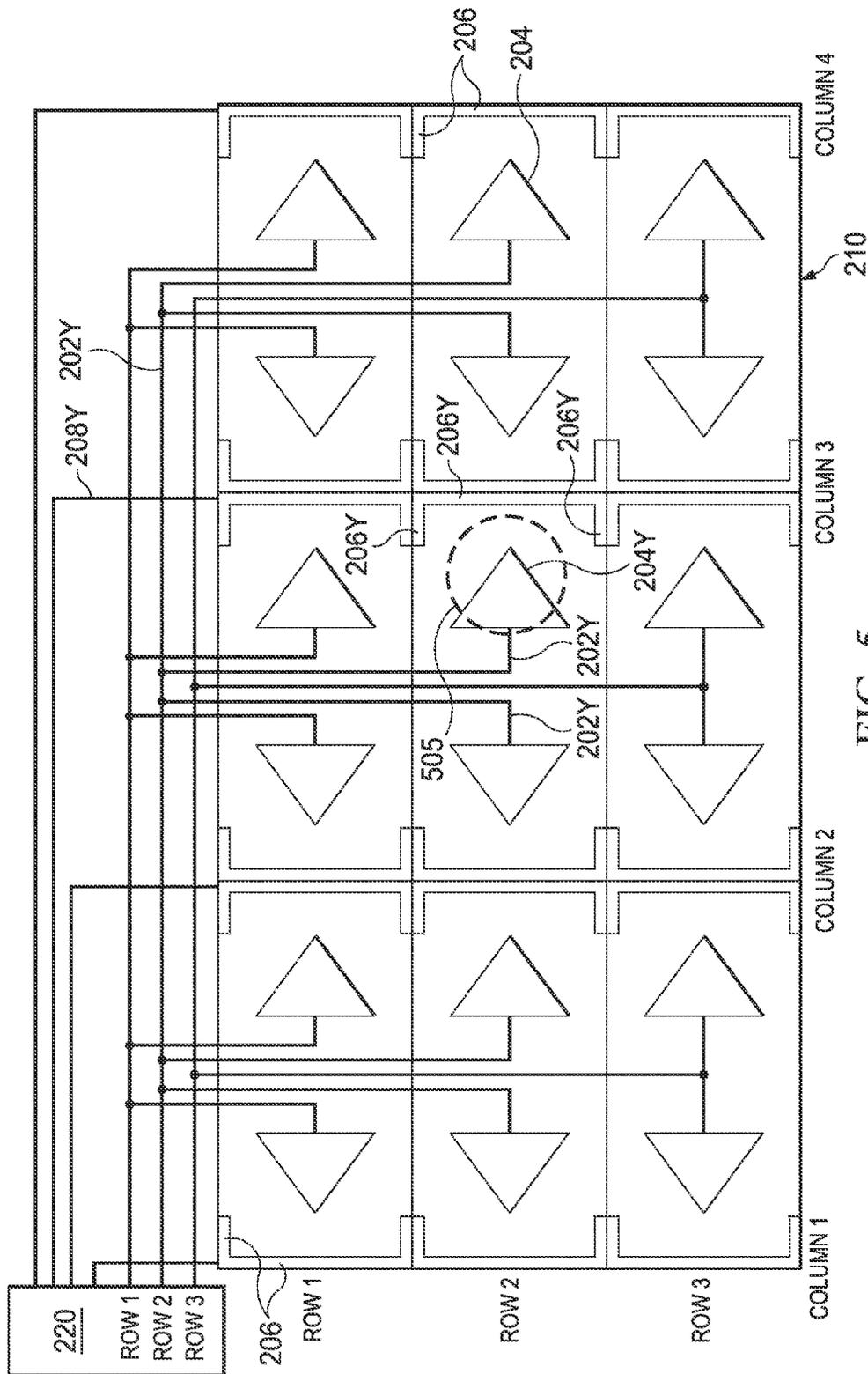


FIG. 5

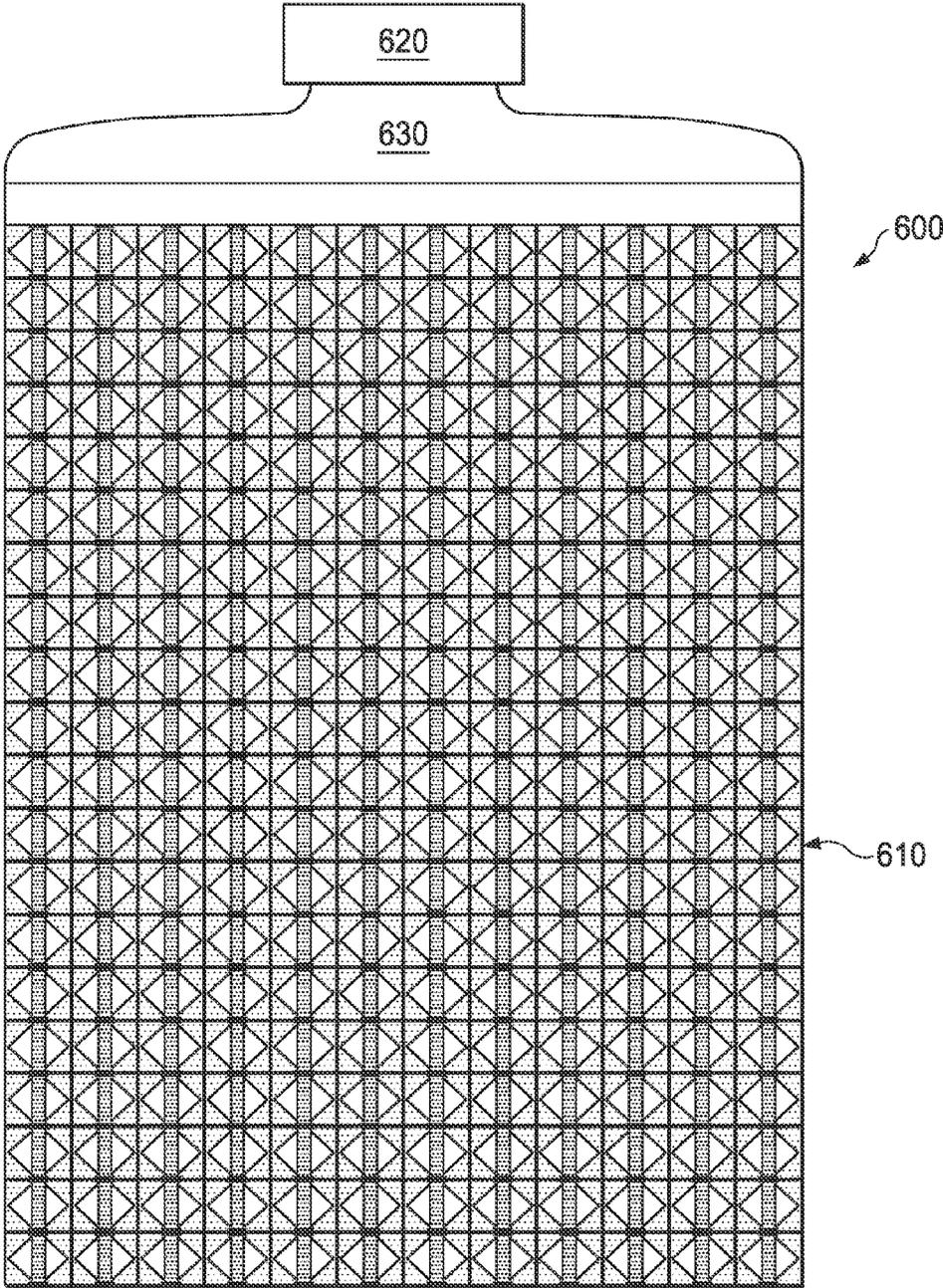
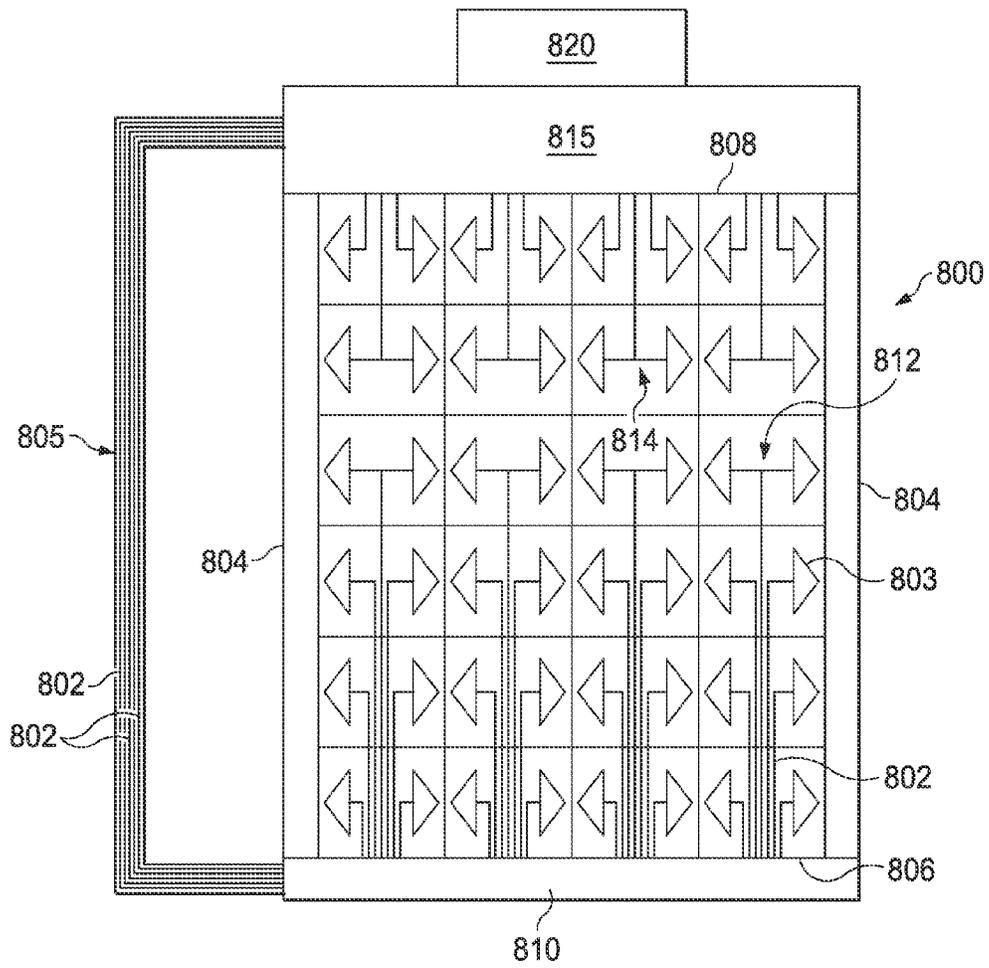


FIG. 6

FIG. 8



SINGLE LAYER SENSOR PATTERN

FIELD OF THE INVENTION

The present disclosure generally relates to capacitive touchscreen panels and, more particularly, to a single layer indium tin oxide (ITO) sensor pattern for use in a capacitive touchscreen panel.

BACKGROUND

Touchscreen panels are typically incorporated in various electronic devices to detect a user input (i.e., user touch) and to display content. The touchscreen panels include an active portion capable of detecting the user touch and displaying content. This active portion is typically formed from multiple layers of sensing circuitry, wherein each layer includes sensing nodes and routing circuitry for connecting the sensing nodes or other touch-detection circuitry to a controller. Each layer of sensing circuitry contributes to the manufacturing expenses and limitations for fabricating the touchscreen panels. Thus, it may be beneficial to reduce the number of layers of sensing circuitry used to fabricate touchscreen panels.

SUMMARY

The present disclosure provides a capacitive sensing structure, comprising: a matrix of sensor cells, wherein each sensor cell comprises: a pair of transmit electrodes separated by a channel, the pair of transmit electrodes including a first transmit electrode and a second transmit electrode, a set of force lines disposed within the channel and connecting the pair of transmit electrodes in parallel with other pairs of transmit electrodes in a row of sensor cells, and one or more sensing electrodes disposed on opposite sides of the sensor cell and adjacent respective ones of the first and second transmit electrodes; wherein respective columns of sensor cells are connected by sets of force lines disposed along the channels of respective sensor cells in the column, each of the sets of force lines terminating at respective pairs of transmit electrodes comprising the sensor cells in the column; and sense lines coupled to the sensing electrodes disposed in a column of sensor cells.

Another embodiment provides a capacitive sensing structure, comprising: a first sensing electrode extending in a first direction along a first edge of a sensing cell; a second sensing electrode extending in the first direction along a second edge of the sensing cell; a pair of transmit electrodes arranged adjacent to each other in a second direction at least substantially perpendicular to the first direction; a channel region extending in the first direction between the pair of transmit electrodes; a first transmit conductor extending in the first direction through the channel region of the sensing cell; a second transmit conductor extending in the first direction parallel to the first transmit conductor within the channel region and terminating in the cell in electrical contact with a first one of the pair of transmit electrodes; and a third transmit conductor extending in the first direction parallel to the first transmit conductor within the channel region and terminating in the cell in electrical contact with a second one of the pair of transmit electrodes.

Yet another embodiment provides a capacitive sensing structure, comprising: a matrix of sensing cells arranged in rows and columns, wherein each sensing cell comprises: a first sensing electrode extending in a first direction; a pair of transmit electrodes arranged adjacent to each other in a second direction at least substantially perpendicular to the first

direction; and a channel region extending in the first direction between the pair of transmit electrodes; wherein the first sensing electrodes of a plurality of sensing cells in each column are electrically connected in series to form a column sensing line; a first transmit conductor extending in the first direction through the channel regions of a plurality of sensing cells in one column and electrically contacting the pair of transmit electrodes in one of the sensing cells; a second transmit conductor extending in the first direction through the channel regions of the plurality of sensing cells in said one column parallel to the first transmit conductor and terminating in another one of the sensing cells in electrical contact with a first one of the pair of transmit electrodes; and a third transmit conductor extending in the first direction through the channel regions of the plurality of sensing cells in said one column parallel to the first transmit conductor and terminating in said another one of the sensing cells in electrical contact with a second one of the pair of transmit electrodes.

Another embodiment provides a capacitive sensing structure, comprising: columns of parallel-connected force trees, wherein each force tree forms a column of sensor cells and comprises: pairs of transmit electrodes extending along the column of sensor cells, each pair of transmit electrodes including a first transmit electrode connected in parallel with a second transmit electrode, and sets of force lines, each set of force lines connecting a pair of transmit electrodes to control circuitry and connecting the pair of transmit electrodes in parallel with other pairs of transmit electrodes in other respective force trees to form a row of sensor cells; columns of sensing electrodes each disposed between the columns of parallel-connected force trees; and sense lines connected to each column of sensing electrodes.

The foregoing and other features and advantages of the present disclosure will become further apparent from the following detailed description of the embodiments, read in conjunction with the accompanying drawings. The detailed description and drawings are merely illustrative of the disclosure, rather than limiting the scope of the invention as defined by the appended claims and equivalents thereof.

BRIEF DESCRIPTION OF DRAWINGS

Embodiments are illustrated by way of example in the accompanying figures not necessarily drawn to scale, in which like numbers indicate similar parts, and in which:

FIG. 1 illustrates an example of a bordered touchscreen panel;

FIG. 2A illustrates an embodiment of a touchscreen panel incorporating a single ITO layer design;

FIG. 2B illustrates a first representative embodiment of a sensor cell incorporated in the touchscreen panel provided in FIG. 2A;

FIG. 2C illustrates a second representative embodiment of a sensor cell incorporated in the touchscreen panel provided in FIG. 2A;

FIG. 3 illustrates an example embodiment of a design wherein force trees are used to form rows of sensor cells;

FIG. 4 illustrates the design of FIG. 3 updated to include columns of sense lines and sensor bars;

FIG. 5 illustrates an example embodiment wherein the design of FIG. 4 is used to detect a user touch;

FIG. 6 illustrates an embodiment of the disclosed single ITO layer design implemented in a borderless touchscreen panel;

FIG. 7 illustrates an embodiment of the disclosed single ITO layer design wherein at least a portion of the force lines are routed along sides of the touchscreen panel; and

FIG. 8 illustrates another embodiment of the disclosed single ITO layer design wherein at least a portion of the force lines are routed using an FPCB tail.

DETAILED DESCRIPTION OF THE EMBODIMENTS

FIG. 1 illustrates an example of a touchscreen panel **100**, such as that typically used in an electronic device such as a smart phone, GPS device, tablet computer, mobile media player, remote control device, or any other devices capable of using a touchscreen panel. The touchscreen panel **100** includes an active portion **110** capable of displaying content and detecting a user touch. The touchscreen panel **100** is formed from multiple ITO layers, namely, first ITO layer **112** and second ITO layer **114**, disposed within the perimeter of the active portion **110**. The first and second ITO layers **112** and **114** are separated by a dielectric layer **116**. The first ITO layer **112** includes columns of interconnected capacitive-sensing nodes **113**, and a first layer of traces **115A** coupled to each column of capacitive-sensing nodes **113** in the first ITO layer **112**. The second ITO layer **114** includes rows of interconnected capacitive-sensing nodes **113**, and a second layer of traces **115B** coupled to each row of capacitive-sensing nodes **113** in the second ITO layer **114**. The first and second layers of traces **115A** and **115B** couple each respective row or column of capacitive-sensing nodes **113** to control circuitry **120**. The control circuitry **120** may include circuitry for providing current to the ITO layers **112** and **114** and detecting signals generated by the capacitive-sensing nodes **113**. The control circuitry **120** may also include logic circuitry for processing signals and conveying touch information to other parts of the electronic device, such as a processor.

As shown in FIG. 1, the layers of traces **115A** and **115B** occupy space along the perimeter of the touchscreen panel **100**, resulting in border areas **117** and **118**. The border areas **117** and **118** provide a region where the layers of traces **115A** and **115B** may be routed to respective columns and rows of interconnected capacitive-sensing nodes **113**. The border areas **117** and **118** are not placed over the active portion **110** and generally do not function as part of an active area of the touchscreen panel **100**. As a result, an inactive border region **123** (also referred to as a border) surrounds the active portion **110** of the touchscreen panel **100**, thereby limiting the available portion of the touchscreen panel **100** to be used for touch sensing and/or display purposes.

FIG. 2A illustrates an embodiment of a touchscreen panel **200** incorporating a single ITO layer design, wherein the touchscreen panel **200** may be incorporated in an electronic device such as a smart phone, GPS device, tablet computer, mobile media player, remote control device, or any other devices capable of implementing a touchscreen panel. The touchscreen panel **200** includes an active portion **205** capable of displaying content and detecting a user touch (e.g., finger, stylus, etc.). The active portion **205** comprises a matrix of sensor cells **210** capable of detecting a user touch. Control circuitry **220** is also illustrated in FIG. 2A. The control circuitry **220** may include logic circuitry for processing signals and conveying touch information to other parts of the electronic device, such as a processor.

As illustrated in the following figures and explained in greater detail below, the matrix of sensor cells **210** is formed from a single ITO layer of capacitive sensor pads, sensor bars, force lines and sense lines (also referred to herein as transmit electrodes, sensing electrodes, transmit lines, and sensing lines, respectively). By incorporating a single ITO layer design, the touchscreen panel **200** may be manufactured at a

lower cost (compared to multiple ITO layer designs) while maintaining the same functionality as a conventional touchscreen panel formed of multiple ITO layers, such as that illustrated in FIG. 1 and described above. Furthermore, by utilizing a single ITO layer design, the touchscreen panel **200** may be more easily incorporated in a borderless design, that is, a design wherein the touchscreen panel **200** lacks the aforementioned inactive border region along all but one side of the active portion **205**. A borderless touchscreen panel may exploit the space dedicated to the touchscreen panel by not requiring additional room for inactive border regions. Thus, the active area of a borderless touchscreen panel may be larger than the active area of a bordered touchscreen panel that would otherwise be installed in a particular device.

A first representative embodiment of one of the sensor cells **210** is illustrated in FIG. 2B. The sensor cell **210** in FIG. 2B is formed from a single ITO layer disposed above a supporting substrate **201**. The single ITO layer includes a pair of opposed sensor pads **204** connected to force lines **202** and a pair of sensor bars **206** connected to sense lines **208**. The opposed sensor pads **204** are centered within the sensor cell **210** and are separated by a channel **205** that is generally defined by the distance between opposing sides **204A** of the sensor pads **204**. Sets of force lines **202** are disposed within the channel **205** to connect respective pairs of sensor pads **204** to the control circuitry **220**. As explained in greater detail below, each set of force lines **202** also connects the pair of sensor pads **204** in parallel with other sensor pads comprising other sensor cells in the same row as the sensor cell **210** shown in FIG. 2B. As shown in FIG. 2B, the set of force lines **202A** terminate at the opposed sides **204A** of the sensor pads **204**, whereas remaining sets of force lines **202B** continue within the channel **205**, to connect to downstream pairs of sensor pads **204** in the present column of sensor cells. Again, although it is not shown in the embodiment illustrated in FIG. 2B, the set of force lines **202A** also connects the pair of sensor pads **204** in parallel with other pairs of sensor pads in the same row.

The sensor bars **206** are generally disposed adjacent the sensor pads **204** along the lateral edges of the sensor cell **210** and include a vertical segment **206A** and horizontal segments **206B**. The closest portions of the vertical segments **206A** are spaced apart from the adjacent sensor pads **204** by a first distance d_1 , and the horizontal segments **206B** are spaced apart from the adjacent sensor pads **204** by a second distance d_2 . In some embodiments, the distances d_1 and d_2 may be equal to each other, or may differ so long as a capacitance formed between the sensor bars **206** and adjacent sensor pads **204** may be properly measured. To this end, the sensor bars **206** are separated from adjacent sensor pads **204** and force lines **202** by an overlying dielectric layer.

The sensor bars **206** are connected to the control circuitry via sense lines **208**. The sense lines **208** are connected to the sensor bars **206** of the first row of sensor cells **210** in the matrix. The sensor bars **206** extend along the length of the matrix of sensors **210** to form a column of sensor bars **206** on both sides of the sensor cells **210**, wherein each column of sensor bars **206** is connected to the control circuitry **220** via the sense lines **208** and interposed sensor bars **206**. It should be appreciated that, in some embodiments, the sensor cell **210** may only include sensor bars **206** on a single side of the sensor cell **210**. In such an embodiment, an outside column of sensor cells **210** in the matrix may either: i) not provide sensing capabilities, or ii) include the sensor bars **206** on both sides of the sensor cells **210** in the outside column to provide full sensing capabilities.

A second representative embodiment of one of the sensor cells **210** is illustrated in FIG. 2C. The sensor cell **210** in FIG. 2C is formed from a single ITO layer disposed above a supporting substrate **201**, and is similar to that illustrated in FIG. 2B and described above, except that the sensor cell **210** of FIG. 2C includes a greater number of horizontal sensor bar segments **206B**. As shown in FIGS. 2B and 2C, because the sensor pads **204**, force lines **202**, sensor bars **206** and sense lines **208** are fabricated of a single ITO layer, they are generally aligned in a consistent (e.g., vertical) orientation to avoid any overlap and subsequent shorted connections.

FIGS. 2B and 2C also illustrate the control circuitry **220** coupled to the force lines **202** and sense lines **208** for processing signals to detect and process a user touch. In general, the control circuitry **220** applies a drive signal to force lines **202** connected to the sensor pads **204** to generate a mutual capacitance between the sensor pads **204** and adjacent sensor bars **206**. A user touch at the location of the sensor cell **210** affects the mutual capacitance formed between the sensor pads **204** and adjacent sensor bars **206**. The capacitance between the sensor pads **204** and adjacent sensor bars **206** is then sensed by the control circuitry **220** using sense lines **208** connected to the sensor bars **206**. Based on the signals received via the sense lines **208**, the control circuitry **220** is capable of performing various operations including detecting the presence of a user touch, resolving the location of the user touch relative to the matrix of sensors **210**, and providing a signal for controlling other circuitry responsive to the detected user touch.

Because the sensor cells **210** are formed using a single ITO layer design, rows of sensor cells **210** and, more particularly, rows of sensor pads **204** cannot be connected in series due to interposed columns of sensor bars **206**. Accordingly, FIG. 3 illustrates an example embodiment (not shown to scale) of a design wherein columns of multiplexed force lines **202** and sensor pads **204**, referred to collectively as force trees **300**, are used to form virtual rows of sensor cells **210**. FIG. 3 also shows that columns of sensor cells **210** may be formed from columns of parallel-connected force trees **300**.

In FIG. 3, an exemplary representation of three rows (and columns) of sensor cells **210** is shown (without the interposed sensor lines **208** and sensor bars **206**) formed from the force trees **300** extending from the top **302** of the panel towards the bottom **304** of the panel. Furthermore, each column of sensor cells **210** is formed from a single force tree **300**. To ensure consistent measurement sensitivity at each row of sensor cells **210** in the matrix, a consistent resistance is maintained along the lengths of each of the force lines **202**. Because the lengths of the force lines **202** in the touchscreen panel may vary in accordance with the locations of the respective sensor cells **210** at which they terminate, the resistance may be controlled by varying the widths of respective force lines **202** so that a consistent resistance can be maintained for all lengths of the force lines **202**. In some embodiments, each force tree **300** is formed such that the force line **202** of the end pair of sensor pads **204** in the force tree **300** has the largest track width, with the force lines **202** of each subsequent pair of sensor pads **204** in the force tree **300** having a reduced track width. For example, with reference to the force tree **300** illustrated in FIG. 3, the set of force lines **202X** extending to the pair of sensor pads **204X** comprising sensor cell **210X** has the greatest length and also has the greatest width (e.g., 200 μm). Subsequent set of force lines **202Y** extending to the pair of sensor pads **204Y** comprising sensor cell **210Y** is shorter than force line **202X** and is split into two branches that have a combined width (e.g., 180 μm) that is less than that of force line **202X**. The last set of force lines **202Z** extending to the

pair of sensor pads **204Z** comprising sensor cell **210Z** is shorter than force lines **202Y** and is also split into two branches that have a combined width (e.g., 150 μm) less than that of combined force lines **202Y**.

Typically, the channel that runs between the pair of sensor pads **204** in a sensor cell **210** is a fixed width to maintain a consistent pitch for each of the sensor cells **210** in the matrix. Naturally, the width of the channel limits the size and number of force lines **202** that may be disposed therein. It will be understood from additional embodiments described herein that, in some embodiments, it is possible to extend the length of a column of sensor cells **210** by adding a force tree **300** that extends from the bottom **304** of the panel towards the top **302** of the panel.

FIG. 4 illustrates the example embodiment of FIG. 3, wherein the rows of sensor cells **210** are shown to include columns of sense lines **208** and sensor bars **206**. As shown in FIG. 4, each column of sensor bars **206** is coupled to the control circuitry **220** via sense lines **208**. In some embodiments, each column of sensor bars **206** in a column of sensor cells **210** may each use a single sense line **208** (e.g., similar to what is shown in FIGS. 2B and 2C). In accordance with the embodiment illustrated in FIG. 4, the control circuitry **220** may provide a drive signal to the force lines **202** of particular rows of sensor pads **204** in each of the force trees **300** to generate a mutual capacitance between those rows of sensor pads **204** in the force tree **300** and adjacent sensor bars **206**. The mutual capacitance formed between the driven rows of sensor pads **204** and adjacent sensor bars **206** is then sensed, or measured, by the control circuitry **220** using the sense lines **208**. The control circuitry **220** then resolves the location of a user touch in the matrix of sensor cells **210** by sensing a change in the mutual capacitance, and determining the location of the change in mutual capacitance by comparing the row of sensor pads **204** to which the drive signal was applied with the column corresponding to the sense line(s) **208** on which the change in mutual capacitance was sensed.

For example, FIG. 5 illustrates an example embodiment wherein the control circuitry **220** applies the drive signal to the force lines **202Y** connected to the sense pads **204Y** located in Row 2. In this embodiment, a user touch (represented by dashed circle **505**) affects the mutual capacitance formed between sense pad **204Y** and adjacent sensor bars **206Y** located at Column 3. Accordingly, a corresponding change in mutual capacitance is sensed on sense line **208Y**. The control circuitry **220** then determines that the user touch **505** occurs near the intersection of the row of active sense pads **204** (Row 2) and the column corresponding to the sense lines **208Y** sensing the change in capacitance (Column 3).

The embodiment illustrated in FIGS. 3-5 corresponds to an implementation wherein the force lines **202** and sense lines **208** are routed along a single side of the touchscreen panel **200**. Accordingly, the embodiment of the touchscreen panel **200** illustrated in FIGS. 3-5 may be incorporated in a borderless touchscreen panel design. Such designs may route the single ITO layer of sense lines **208** and force lines **202** to the control circuitry **220** using an external flexible printed circuit board (FPCB) mounted to the touchscreen panel **200**. An example of a borderless touchscreen panel **600** (having an active portion **610**) coupled to control circuitry **620** via an FPCB **630** is illustrated in FIG. 6.

The disclosed single ITO layer touchscreen design is not limited to borderless touchscreen panels. For example, FIG. 7 illustrates an example embodiment of a touchscreen panel **700** wherein at least a portion of the force lines **702** are routed along sides **704** of the panel **700** and coupled to sensor pads **705** from the bottom side **706** of the panel **700**, using an FPCB

710, to form force trees 712 extending from the bottom side 706 of the panel 700. The sense lines (not shown) and remaining force lines 702 are routed from the top side 708 of the panel 700 such that the sense lines are connected to columns of sensor bars (not shown), and the remaining force lines 702 are coupled to sensor pads 705 to form force trees 714 extending from the top side 708 of the panel 700. In the embodiment illustrated in FIG. 7, the force lines 702 and sense lines are coupled to control circuitry 720 via an FPCB 715 mounted to the top side 708 of the touchscreen panel 700.

In some embodiments, the force lines 702 routed along the sides 704 of the panel 700 may incorporate a ground ring design as shown in FIG. 7. In such embodiments, this may be accomplished by grounding the outer force lines 702A and transmitting the drive signal using the inner force lines 702B.

FIG. 8 illustrates another example embodiment of a non-borderless touchscreen panel 800. The touchscreen panel 800 is similar to that illustrated in FIG. 7, except that instead of routing force lines 802 along the sides 804 of the panel 800, the force lines are routed to the bottom side 806 of the panel 800 using an FPCB tail 805 extending between a bottom FPCB 810 and a top FPCB 815. As discussed above, at least a portion of the force lines 802 are routed along the FPCB tail 805 and bottom FPCB 810 and are coupled to sensor pads 803 from the bottom side 806 of the panel 800 to form force trees 812 extending from the bottom side 806 of the panel 800. The sense lines (not shown) and remaining force lines 802 are routed from the top side 808 of the panel 800 such that the sense lines are connected to columns of sensor bars (not shown) and remaining force lines 802 are coupled to sensor pads 803 to form force trees 814 extending from the top side 808 of the panel 800. In the embodiment illustrated in FIG. 8, the force lines 802 and sense lines are coupled to control circuitry 820 via the FPCB 815 mounted to the top side 808 of the touchscreen panel 800.

The foregoing description has provided by way of exemplary and non-limiting examples a full and informative description of one or more exemplary embodiments of this invention. However, various modifications and adaptations may become apparent to those skilled in the relevant arts in view of the foregoing description, when read in conjunction with the accompanying drawings and the appended claims. However, all such and similar modifications of the teachings of this invention will still fall within the scope of this invention as defined in the appended claims.

What is claimed is:

1. A capacitive sensing structure, comprising:

a matrix of sensor cells, wherein each sensor cell comprises:

a pair of transmit electrodes separated by a channel, the pair of transmit electrodes including a first transmit electrode and a second transmit electrode,

a set of force lines disposed within the channel and connecting the pair of transmit electrodes in parallel with other pairs of transmit electrodes in a row of sensor cells, and

one or more sensing electrodes disposed on opposite sides of the sensor cell and adjacent respective ones of the first and second transmit electrodes;

wherein respective columns of sensor cells are connected by sets of force lines disposed along the channels of respective sensor cells in the column, each of the sets of force lines terminating at respective pairs of transmit electrodes comprising the sensor cells in the column; and

electrical connection of the sensing electrodes disposed in a column of sensor cells; and

wherein the transmit electrodes, sensing electrodes and force lines are formed from a single indium tin oxide (ITO) layer.

2. The capacitive sensing structure of claim 1, further comprising control circuitry operable to apply a drive signal to the sets of force lines and to receive a sense signal from the sense lines.

3. The capacitive sensing structure of claim 2, wherein responsive to the drive signal, a set of force lines is operable to generate, for a row of sensor cells, a capacitance between pairs of transmit electrodes and adjacent sense electrodes.

4. The capacitive sensing structure of claim 2, wherein the sense signal is indicative of a capacitance formed between at least one of the first and second transmit electrodes and adjacent sensing electrodes in a sensor cell.

5. A capacitive sensing structure, comprising:

a first electrode extending in a first direction along a first edge of a sensing cell;

a second electrode extending in the first direction along a second edge of the sensing cell;

a pair of third electrodes arranged adjacent to each other in a second direction at least substantially perpendicular to the first direction;

a channel region extending in the first direction between the pair of third electrodes;

a first conductor extending in the first direction through the channel region of the sensing cell;

a second conductor extending in the first direction at least substantially parallel to the first conductor within the channel region and terminating in the cell in electrical contact with a first one of the pair of third electrodes; and

a third conductor extending in the first direction at least substantially parallel to the first conductor within the channel region and terminating in the cell in electrical contact with a second one the pair of third electrodes.

6. The capacitive sensing structure of claim 5, wherein the first electrode further includes a first plurality of segments extending in the second direction toward the pair of third electrodes.

7. The capacitive sensing structure of claim 6, wherein the second electrode further includes a second plurality of segments extending in the second direction toward the pair of third electrodes.

8. The capacitive sensing structure of claim 5, wherein the first electrode, second electrode and pair of third electrodes are formed on a single conductive layer above a supporting substrate.

9. The capacitive sensing structure of claim 8, wherein the first through third conductors are formed on the same single layer as the first electrode, second electrode and pair of third electrodes.

10. The capacitive sensing structure of claim 5, wherein the first conductor extends from a third edge of the sensing cell to a fourth edge of the sensing cell.

11. The capacitive sensing structure of claim 10, wherein the second and third conductors extend from the third edge of the sensing cell.

12. The capacitive sensing structure of claim 5, wherein the first conductor has a first width and the second and third conductors each have a second width, wherein the second width is less than the first width.

13. The capacitive sensing structure of claim 12, wherein the second width is less than one half of the first width.

14. The capacitive sensing structure of claim 5, further comprising circuitry for electrically connecting the second and third conductors together at a location outside of the sensing cell.

15. The capacitive sensing structure of claim 5, wherein the sensing cell has a square perimeter shape.

16. A capacitive sensor, comprising:

a matrix of sensing cells arranged in rows and columns, wherein each sensing cell comprises:

a first electrode extending in a first direction;

a pair of second electrodes arranged adjacent to each other in a second direction at least substantially perpendicular to the first direction; and

a channel region extending in the first direction between the pair of second electrodes;

wherein the first electrodes of a plurality of sensing cells in each column are electrically connected in series to form a column line;

a first conductor extending in the first direction through the channel regions of a plurality of sensing cells in one column and electrically contacting the pair of second electrodes in one of the sensing cells;

a second conductor extending in the first direction through the channel regions of the plurality of sensing cells in said one column at least substantially parallel to the first conductor and terminating in another one of the sensing cells in electrical contact with a first one of the pair of second electrodes; and

a third conductor extending in the first direction through the channel regions of the plurality of sensing cells in said one column at least substantially parallel to the first conductor and terminating in said another one of the sensing cells in electrical contact with a second one of the pair of second electrodes.

17. The capacitive sensor of claim 16, further comprising force circuitry coupled to the first, second and third conductors and configured to apply a force signal.

18. The capacitive sensor of claim 17, further comprising sense circuitry coupled to the column line and configured to receive a sense signal.

19. The capacitive sensor of claim 17, wherein the second and third conductors are electrically connected to receive a same force signal.

20. The capacitive sensor of claim 19, wherein each column of the matrix includes the first, second and third conductors.

21. The capacitive sensor of claim 20, wherein the first transmit conductors of the plurality of columns are electrically connected to receive a same force signal and thus activate the pairs of transmit electrodes in a row of the matrix.

22. The capacitive sensor of claim 20, wherein the second and third conductors of the plurality of columns are electrically connected to receive a same force signal and thus activate the pairs of second electrodes in a row of the matrix.

23. The capacitive sensor of claim 16, further comprising a third electrode extending in the first direction, wherein the

third electrodes of a plurality of sensing cells in each column are electrically connected in series to form another column line.

24. The capacitive sensor of claim 23, wherein the first and third electrodes are positioned on opposite edges of the sensing cell.

25. The capacitive sensor of claim 24, wherein the third electrode further includes a plurality of sense segments extending in the second direction toward the pair of second electrodes.

26. The capacitive sensor of claim 16, wherein the first electrode further includes a plurality of sense segments extending in the second direction toward the pair of second electrode.

27. The capacitive sensor of claim 16, wherein the first electrode and pair of second electrodes are formed on a single conductive material layer above a supporting substrate.

28. The capacitive sensor of claim 27, wherein the first through third conductors are formed on the same single conductive material layer as the first electrode and pair of second electrodes.

29. The capacitive sensor of claim 16, wherein the first conductor extends from an edge of the sensing cell to an opposite edge of the sensing cell.

30. The capacitive sensor of claim 29, wherein the second and third conductors extend from said edge of the sensing cell.

31. The capacitive sensor of claim 16, wherein the first conductor has a first width and the second and third conductors each have a second width, wherein the second width is less than the first width.

32. The capacitive sensor of claim 31, wherein the second width is less than one half of the first width.

33. The capacitive sensor of claim 16, wherein each sensing cell has a square perimeter shape.

34. A capacitive sensing structure, comprising:

columns of parallel-connected force trees, wherein each force tree forms a column of sensor cells and comprises: pairs of transmit electrodes extending along the column of sensor cells, each pair of transmit electrodes including a first transmit electrode connected in parallel with a second transmit electrode, and

sets of force lines, each set of force lines connecting a pair of transmit electrodes to control circuitry and connecting the pair of transmit electrodes in parallel with other pairs of transmit electrodes in other respective force trees to form a row of sensor cells;

columns of electrically connected sensing electrodes each disposed between the columns of parallel-connected force trees; and

wherein the force trees and sensing electrodes are formed from a single indium tin oxide (ITO) layer.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

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INVENTOR(S) : Chee Yu Ng et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the claims,

At column 10, claim number 26, line number 14, please replace the word [electrode] with

-- electrodes --.

Signed and Sealed this
Sixteenth Day of August, 2016



Michelle K. Lee
Director of the United States Patent and Trademark Office